Michigan State University

National Superconducting Cyclotron Laboratory

A SIMPLE TWO-DIMENSIONAL PPAC

D. SWAN, J. YURKON, and D.J. MORRISSEY

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D. SWAN, and J. YURKON

National Superconducting Cyclotron Laboratory

Michigan State University

E. Lansing, MI 48824

D. J. MORRISSEY

Department of Chemistry and

National Superconducting Cyclotron Laboratory

Michigan State University

E. Lansing, MI 48824

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Abstract

A two-dimensional position sensitive parallel-plate avalanche (PPAC) detector developed for routine use in the MSU/NSCL fragment separator is described. Each 2D-PPAC provides reasonably accurate position measurements over its 10 x 10 cm^2 aperture for a very large range of energetic ions. The detectors are relatively low cost and can be easily rebuilt if the pressure windows fail. Numerous complete devices have been constructed and have been used routinely at the NSCL and other laboratories. Typical results for the time and position resolution of the detectors are reported.

Typeset using REVTEX

I. INTRODUCTION

The production of radioactive secondary beams in many laboratories has recently opened a broad area of nuclear science research. The secondary ions have been produced by two related techniques: target fragmentation/ionization/acceleration and projectile fragmentation/separation. The facilities that produce these exotic beams with the latter process of fragmenting heavy-ion projectiles routinely need to measure the positions (rigidity) of a very wide range of energetic ions. For example, the A1200 facility at Michigan State University uses a K = 1200 cyclotron with ECR ion-sources to produce a large number of primary beams with $E/A \sim 100$ MeV. The heavy-ions are reacted at the beginning of a momentum-loss achromat that feeds the rest of the beamlines [1]. Secondary beams from this system have ranged from very penetrating ^{11}Li ions with $E/A{\sim}80$ MeV [2], through the highly ionizing ^{89}Ru with $E/A{\sim}60$ MeV [3], to even heavier ions. The ions are dispersed at images in the achromat over areas approximately 10 cm by 5 cm, and it is often necessary to make four (two-dimensional) position measurements to track the particles through the separator. Uniform detector thickness is extremely important in situations with such a large number of position measurements, and wire meshes along the ion's path are not generally acceptable.

The prime design criteria were that the detectors should: (1) provide reasonable position resolution, ≈1 mm, over the entire active area of 10 x 10 cm with a minimum external frame, (2) introduce only uniform energy-losses to the particles independent of position, (3) respond to a wide variety of heavy-ions, and (4) be simply constructed and relatively easy to assemble and repair. To fulfill these needs we have developed a two-dimensional parallel plate avalanche detector (2D-PPAC) based on charge-division readout and a very simple mechanical design. Two dimensional parallel-plate avalanche detectors have been used in various heavy-ion detector applications over a number of years [4,5], but have not been widely used in spectrometer systems.

During the past three years, the new 2D-PPACs been used in essentially every secondary beam experiment at the NSCL. The detectors have proven to be very versatile and reliable. Copies of the detectors have been used at several other laboratories. In Section II, the design and construction of the 2D-PPAC is presented. Then the results for measurement of the position and time resolution in are given in Section III.

II. CONSTRUCTION AND OPERATION

The general principles and construction of parallel-plate avalanche detectors are well known (cf. [4,5] and references therein). The present device has two separate parallel planar electrodes on either side of a central biased electrode to measure the positions of particles that are incident normal to the electrodes. Two independent avalanches are created by the passage of a particle through the detector. Each position is obtained from the signal induced on a striped readout foil connected to a resistive divider chain. The four signals at the ends of the two chains are amplified, shaped and the peak voltages recorded.

The detector's active area of 10 x 10 cm^2 was determined by the area of the focal plane (10 x 5 cm^2) and a desire for symmetrical construction. The gap between the foils of approximately 3 mm was chosen to provide sufficient ionization from the most penetrating ions. The mechanical design of the detector is indicated in Fig. 1. It consists of five foils each mounted on a set of four G-10 boards compressed between two aluminum frames, Fig. 1-A,. The ≈3 mm (one-eighth inch) thickness of the readout circuit boards creates two central gas volumes for avalanches with a common center electrode. The two central circuit boards, Fig. 1-C, sandwich a double sided electrode. These two readout circuit boards with striped foils and the resistive divider chains are identical, see Fig. 2. The G-10 window spacers, Fig. 1-B, carry the pressure windows and gas connections.

As can be seen in Fig. 2, each readout board has contacts for both horizontal and vertical readout stripes but is loaded with only one set of eighty 100 Ω chip-resistors for the divider chain. Electrical contact between these readout circuit boards and the foils is maintained by mechanical compression.

The two pressure windows are commercial 1.5 μm aluminized polyester foils. The three inner foils are stretched polypropylene. The center electrode has aluminum evaporated onto both sides of a 0.75 μm thick polypropylene foil. The readout foils are striped by evaporating aluminum through a mask onto the similar polypropylene foils. The stripes have a center-to-center separation of 1.3 mm (0.050 inch) and a gap of 0.51 mm (0.020 inch).

The detectors are build up in layers and are sealed with HYLOMAR® (Marsten Lubricants) sealant for easy disassembly. The interchangeability of circuit boards allowed a reasonable inventory of components to be maintained and the rapid assembly of replacement detectors when needed. Approximately 20 complete devices have been constructed and used. The components, except the foils, are rugged and mechanical failures are unusual (<5%), even after numerous disassemblies involving extensive cleaning and handling. However, the contact between the resistor-chain taps and the stripes on the readout foils in working detectors seems to degrade after extensive use ($\sim 10^{10}$ avalanches) and the signal size diminishes.

The detectors are usually operated in pairs for trajectory measurements and filled with iso-octane (2,2,4,-trimethylpentane). Iso-octane is a low-boiling organic liquid with a vapor pressure of approximately 48 torr at 25° C. Reagent grade liquid is placed in a valved container and connected to a gas manifold. The gas, at 5 to 7 torr, is flowed through the two detectors in series at a relatively low rate, typically ~2 std cm^3/min. A constant gas pressure is maintained with a compact gas manifold based on a electronic-manometer controlled valve. (Ballasted mechanical pumps should be used to flow this gas.) Isobutane has also been used but this lower density gas was not as useful for the very penetrating ions.

III. RESULTS

A negative bias of approximately 600 volts (across the ~3 mm gap) is typically applied to the central electrode foil at 5 torr pressure. This produces signals with a fast component on the order of -5 mV at each end of the two resistive chains. The size of the fast-component signal (without amplification) was measured as function of pressure and is indicated in Table I. During normal operation, the four position signals are passed through charge sensitive preamplifiers before long cables (≈100 m) to the counting area. The signals then pass through shaping amplifiers (Gaussian time constant of ~ 1μs) and into peak-sensitive ADC's. Under these operating conditions the center-electrode foil provides a positive-going fast signal that can be inverted and amplified to provide a reference time signal. The strobe signal for each ADC is usually generated by a separate fast-timing detector but can be derived from the center-electrode signal or from the preamplified position signals. The two positions are then calculated in software from the four analogue signals.

The time resolution of two PPACs was measured with an alpha source (^{241}Am). For this test, positive high voltages (approximately 610 volts) were used so that a negative-going signal would be produced by the central electrode. These signals were amplified and sent to constant fraction discriminators and then a time-to-amplitude converter. The spectrum, shown in Fig. 4, contains a sharp peak (the second peak was created by delaying the stop-signal by 5.0 ns to provide a calibration). The FWHM of the distribution is ~0.6 ns, and so the time resolution of a single detector is $\sim 0.6/\sqrt{2} = 0.42$ ns.

The results of a typical position calibration of a 2D-PPAC can be seen in Fig. 4. A beam of ^{18}O ions at E/A = 80 MeV was used to irradiate a mask in front of the device. The mask had a series of 1.6 mm (1/16 inch) diameter holes with 1.0 cm gaps. The calculated horizontal and vertical positions of the particles are displayed in a scatter plot in Fig. 4a, and a histogram of the calculated positions of particles that passed through the central row of holes is shown in Fig. 4b. The peaks are well described by Gaussian functions. The centroids are linear with position in each dimension and the σ values of the peaks are a constant, 0.90 mm (FWHM = 2.1 mm). If we assume that the holes contribute 2/3 of their diameter in quadrature to the observed position resolution, then the intrinsic resolution is $\sigma \approx 0.8$ mm, (FWHM = 1.8 mm).

IV. CONCLUSIONS

We have described the construction and use of a very simple two-dimensional parallel plate avalanche counter. The devices have provided straightforward two-dimensional position measurements for a large variety of energetic heavy-ions in the NSCL-A1200 projectile fragment separator and elsewhere. A relatively large number of 2D-PPACs have been produced and remanufactured after the windows have been inadvertently broken, thus proving the utility of the design.

ACKNOWLEDGMENTS

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TABLES

TABLE I. Measurement of the peak voltage in the fast component as a function of Iso-octane pressure. The maximum operating voltage applied to the central electrode before breakdown is indicated.

Pressure (torr)	Applied Voltage (volts negative)	Reduced Field (V/mm-torr)	Fast Component Peak (mV negative)
3.02	570	63.	2.5
4.02	640	53.	5
4.97	660	44.	5
5.50	715	43.	6
6.01	740	41.	9
7.05	820	39.	13
8.01	880	37.	15
8.98	930	35.	15

FIGURES

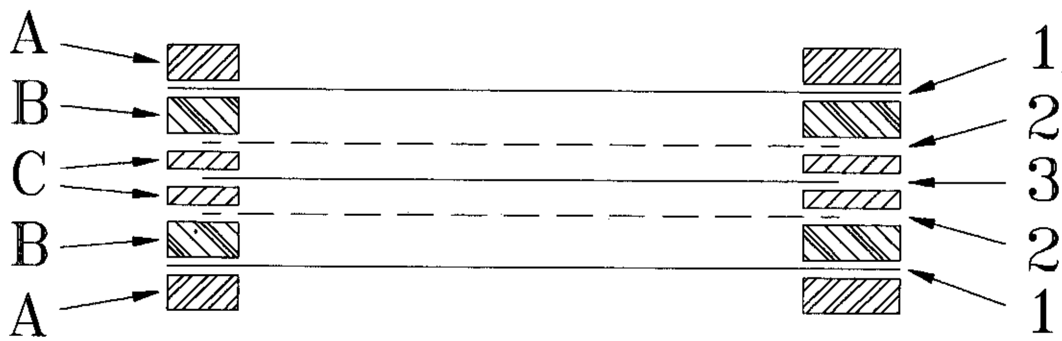

FIG. 1. A cross sectional view of the PPAC. The printed circuit boards, labeled A, B, and C, and the foils, labeled 1, 2, and 3, are described in the text.

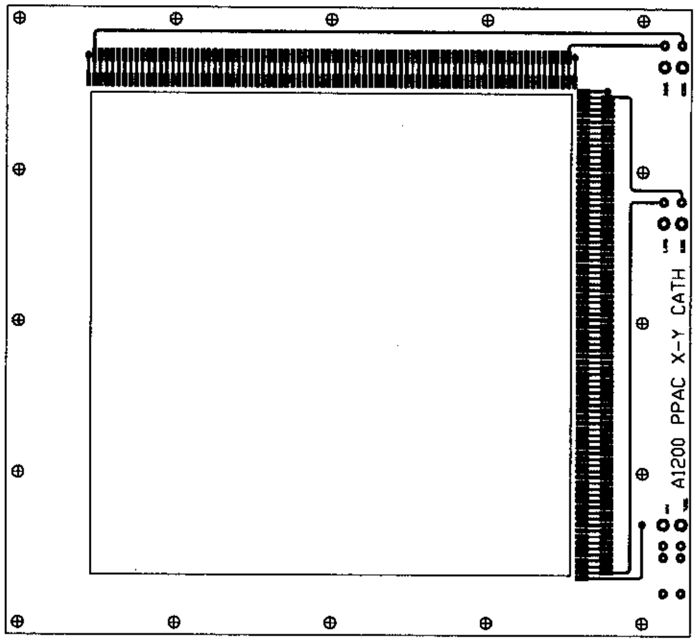

FIG. 2. A representation of the circuit board with both pairs of contacts to connect the striped foil to resistive divider chains. Only one set of resistors is mounted on each readout board, see the text.

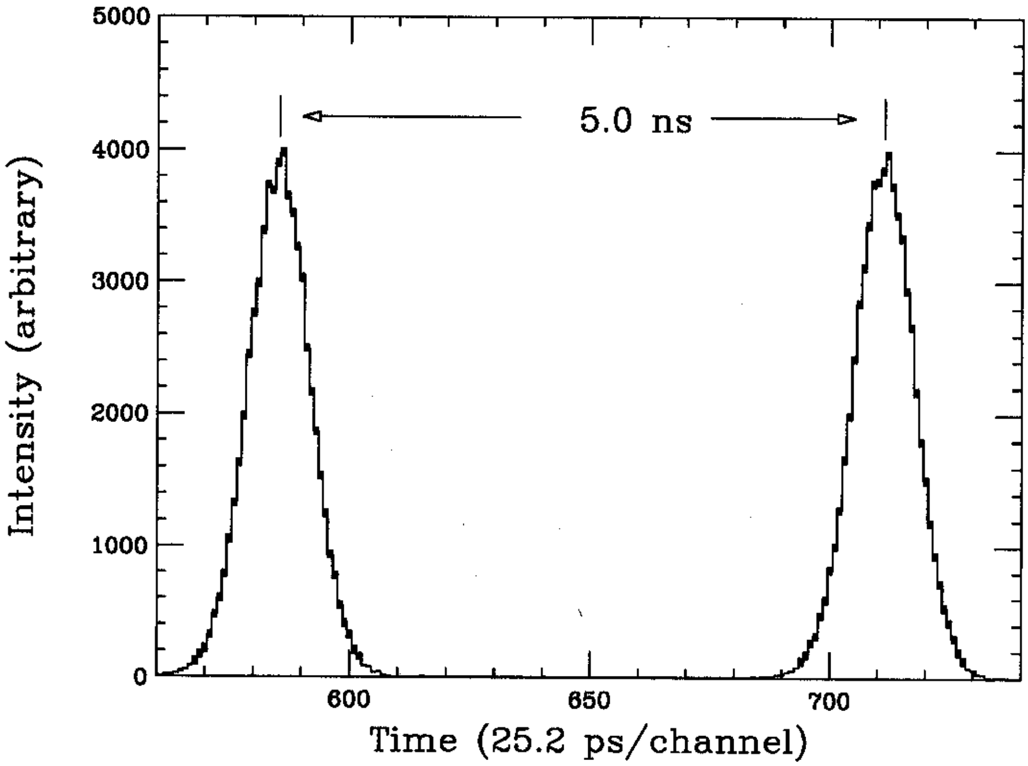

FIG. 3. Time of flight distribution for alpha particles traveling between two parallel plate counters. The fight-hand peak was obtained by adding a 5.0 ns cable delay to the stop signal.

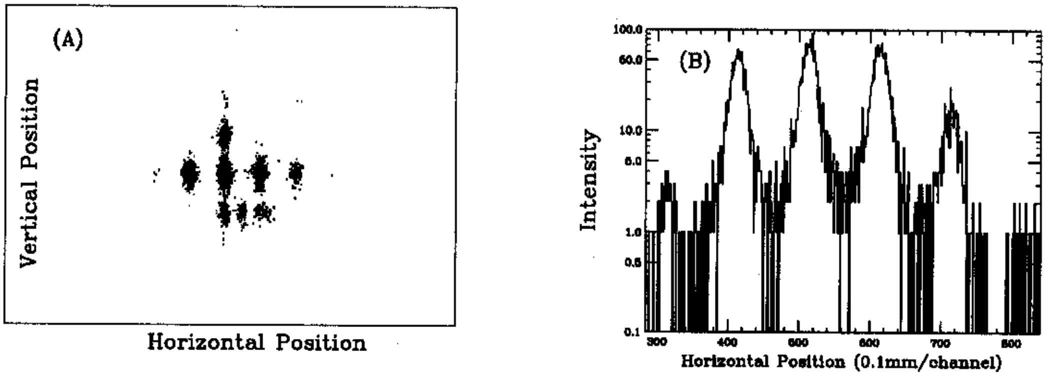

FIG. 4. Typical results from a position calibration with a ^{18}O beam at E/A=80 MeV. (A), two-dimensional scatter plot of the calculated positions of particles that passed through a mask. (B), expanded histogram of events that passed through the center horizontal row of holes in the mask. The holes were separated by 1.0 cm but the mask was not uniformly illuminated, rather particles were swept across the surface. Therefore, the relative intensities are not meaningful.